UNIVERSITI SAINS MALAYSIA

Final Examination
Academic Session 2008/2009

April 2009

JIF 317 – Atomic Physics
[JIF 317 – Ilmu Fizik Atom]

Time : 3 hours
[Masa : 3 jam]

Please ensure that this examination paper contains **SEVEN** printed pages before you begin the examination.

Answer **ALL** questions. You may answer **either** in Bahasa Malaysia or in English.

Read the instructions carefully before answering.

Each question carries 100 marks.

*Sila pastikan bahawa kertas peperiksaan ini mengandungi **TUJUH** muka surat yang bercetak sebelum anda memulakan peperiksaan ini.*

*Jawab **SEMUA** soalan. Anda dibenarkan menjawab soalan **sama ada** dalam Bahasa Malaysia atau Bahasa Inggeris.*

Baca arahan dengan teliti sebelum anda menjawab soalan.

Setiap soalan diperuntukkan 100 markah.

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1. (a) With the aid of a diagram, explain the Thomson and Rutherford Model of an atom emphasizing on their strength and weaknesses.

(25 marks)

(b) Describe the Bohr model of an atom. Explain how the Bohr Model overcomes the shortcomings of the Rutherford Model?

(25 marks)

(c) Using Bohr Model, describe the origin of the line spectra.

(25 marks)

(d) The longest wavelength in Lyman series for hydrogen atom is 1215Å. Calculate the Rydberg constant.

(25 marks)

2. (a) Prove that the equation

$$\Phi_m = \left(\frac{1}{\sqrt{2\pi}}\right) e^{im\phi}$$

satisfies the differential equation

$$\frac{d^2\Phi}{d\phi^2} + m^2\phi = 0$$

Plot the distribution of $\Phi(\phi), \Theta(\theta), R(r)$ and $P(r)dr = r^2 |R_{nl}|^2 dr$. Explain the significance of the plot *P (r) dr* in explaining the existence of the shell and sub-shell in an atom.

(60 marks)

(b) State the principal quantum number, orbital angular momentum quantum number and magnetic quantum number for the 3f and 4f states of hydrogen atom.

(10 marks)

(c) State the selection rule. With the aid of the energy level diagram, sketch the appropriate energy-level diagram showing the transitions allowed by selection rule.

(30 marks)

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3. (a) With the aid of suitable energy level diagrams, explain the Normal Zeeman Effect.

(50 marks)

(b) In Normal Zeeman Experiment, the line of sodium 4226 Å splits into 3 components separated by a distance 0.25 Å when an external magnetic field of 3T is applied. Find the e/m for an electron.

(25 marks)

(c) A wavelength of 5000 Å is observed when no external magnetic field is applied. When an external magnetic field of 0.6T is applied, the transition occurred between state $l = 2$ to $l = 1$. Find the wavelength of the new observed spectrum.

(25 marks)

4. (a) Describe the Stern-Gerlach Experiment and explain how does the result of this experiment can verify the existence of electron spin.

(30 marks)

(b) State the Pauli Exclusion Principle. By considering two identical, indistinguishable and non-interacting particles and the characteristic of symmetric and asymmetric wave functions, derive the Pauli Exclusion Principle.

(30 marks)

(c) State Hund's Rule in arranging the electrons in an atom. What is the significance of this rule to the physical properties of some metals?

(20 marks)

(d) By taking into consideration the Pauli exclusion Principle and Hund's rule, arrange the electrons in an atom with Z = 28 into their n, l, m_l, m_s quantum numbers.

(20 marks)

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5. (a) With the aid of suitable diagram, explain covalent and ionic bonds.

(30 marks)

(b) What is rotational energy of a molecule? By considering a diatomic molecule rotating about its centre of mass, show that the rotational energy of a molecule is given by

$$E_j = \frac{J(J+1)\hbar^2}{2I}$$

where J is the rotational quantum number and I is the moment of inertia.

(40 marks)

(c) The carbon monoxide (CO) molecule has a bond length R of 0.113 nm and the masses of ^{13}C and ^{16}O are 1.99×10^{-26} kg and 2.66×10^{-26} kg respectively. Find

(i) the lowest rotational energy.

(ii) the angular velocity of the CO molecule when it is in its lowest rotational state.

(30 marks)

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1. (a) *Dengan bantuan gambar rajah, jelaskan Model Thomson dan Model Rutherford untuk atom dengan memberikan penekanan terhadap kekuatan dan kelemahannya.*

(25 markah)

(b) *Jelaskan Model Atom Bohr. Bagaimana Model Bohr mengatasi kelemahan Rutherford Model?*

(25 markah)

(c) *Dengan menggunakan Model Bohr jelaskan asal usul spectra garisan.*

(25 markah)

(d) *Jarak gelombang terpanjang siri Lyman untuk atom hidrogen ialah 1215Å. Kira pemalar Rydberg.*

(25 markah)

2. (a) *Buktikan persamaan*

$$\Phi_m = \left(\frac{1}{\sqrt{2\pi}}\right) e^{im\phi}$$

memuaskan persamaan pembezaan

$$\frac{d^2\Phi}{d\phi^2} + m^2\phi = 0$$

Plot taburan $\Phi(\phi), \Theta(\theta), R(r)$ *dan* $P(r)dr = r^2 |R_{nl}|^2 dr$. *Jelaskan kepentingan plot P (r) dr dalam menjelaskan kewujudan petala dan sub-petala dalam atom.*

(60 markah)

(b) *Berikan nombor kuantum prinsipal, nombor kuantum momentum sudut orbitan dan nombor kuantum magnet untuk keadaan 3f dan 4f atom hidrogen.*

(10 markah)

(c) *Nyatakan petua pilihan. Dengan bantuan gambar rajah paras tenaga, lakarkan gambar rajah paras-tenaga yang menunjukkan peralihan yang dibenarkan oleh petua pilihan.*

(30 markah)

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3. (a) *Dengan bantuan gambar rajah paras tenaga yang sesuai, jelaskan Kesan Zeeman Biasa.*

(50 markah)

(b) *Dalam uji kaji Zeeman Biasa, garisan natrium 4226 Å berpecah kepada 3 komponen yang diasingkan oleh jarak 0.25 Å apabila medan magnet luar 3T dikenakan. Cari e/m untuk elektron.*

(25 markah)

(c) *Jarak gelombang 5000 Å dilihat apabila medan magnet luar tidak dikenakan. Apabila medan magnet luar 0.6T dikenakan, peralihan berlaku antara keadaan $l = 2$ to $l = 1$. Cari jarak gelombang spektra yang dilihat.*

(25 markah)

4. (a) *Jelaskan ujikaji Stern-Gerlach dan terangkan bagaimana keputusan ujikaji ini boleh menentusahkan kewujudan spin elektron.*

(30 markah)

(b) *Nyatakan Prinsip Ekslusi Pauli. Dengan mengambil kira dua zarah yang seiras, tidak boleh dibezakan dan tidak bertindak balas dan ciri-ciri gelombang simetri dan tak simentri, terbitkan Petua Ekslusi Pauli.*

(30 markah)

(c) *Nyatakan Petua Hund dalam menyusun elektron dalam atom. Apakah kepentingan petua ini kepada sifat-sifat fizikal untuk sesetengah logam?*

(20 markah)

(d) *Dengan mempertimbangkan Prinsip Ekslusi Pauli dan Petua Hund, susun elektron dalam atom dengan $Z = 28$ dengan menggunakan nombor kuantum n, l, m_l, m_s.*

(20 markah)

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5. (a) *Dengan bantuan gambar rajah yang sesuai, jelaskan ikatan kovalen dan ionik.*

(30 markah)

(b) *Apakah tenaga putaran untuk sesuatu molekul? Dengan mengambil kira molekul diatom berputar di sekitar pusat jisim, tunjukkan tenaga putaran untuk molekul diberikan oleh*

$$E_j = \frac{J(J+1)\hbar^2}{2I}$$

di mana J ialah nombor kuantum putaran dan I ialah momen inertia.

(40 markah)

(c) *Panjang ikatan R, molekul karbon monosida (CO) ialah 0.113 nm dan jisim* ^{13}C *dan* ^{16}O *masing-masing ialah* 1.99×10^{-26} *kg dan* 2.66×10^{-26} *kg. Cari*

(i) *tenaga putaran terendah.*

(ii) *halaju putaran molekul CO apabila berada di keadaan putaran terendah.*

(30 markah)

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